

REQ. NO. 2-9001 .

CONTRACT REPORT NO. OSL 82-00034

Laboratory Report on Preparation of
SPECIMENS FOR DURABILITY OF
PORTLAND CEMENT/FLYASH CONCRETE IN MARINE ENVIRONMENT
PHASE V
for the

DEPARTMENT OF ENERGY, MINES AND RESOURCES

DSS File No. 20Su.23440-2-9001

T. W. Bremner, P. Eng.
Professor of Civil Engineering
University of New Brunswick
Fredericton, New Brunswick
E3B 5A3

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Laboratory Report

1. Introduction

The Department of Civil Engineering of the University of New Brunswick was awarded contracts in 1978, 1979, 1980, 1981 and 1982 by the Department of Supply and Services to prepare large concrete specimens that are to be used by the Department of Energy, Mines and Resources (EMR) in durability studies at the U.S. Corps of Engineers' salt water exposure site at Treat Island, Maine. Copies of these reports can be obtained from EMR in Ottawa. The first two reports cover specimens containing Type 10 and Type 50 cement with varying percentage of cement replacement with slag and fly ash and with aggregate from the Blagdon Pit. The first report also included the use of high range water-reducers. The third report covered the use of slag as a replacement for Type 10 and Type 50 cements in semi-lightweight concrete made from expanded shale aggregates. The fourth report covers the use of Type 10 and Type 50 cement in concrete made from sand from the Blagdon Pit and limestone coarse aggregate from the Brookville Pit. This fifth report covers the use of slag and silica fumes both as a replacement and as an additive to the normal Portland cement. The work statement was amended so as to incorporate 80% slag rather than 50% slag as initially specified. The amended work statement is given in Appendix A.

The Canadian Standards Association Standard A23.1 - 1973 on "Concrete Materials and Methods of Concrete Construction" and A23.2 - 1973 "Methods of Test for Concrete" were followed, unless otherwise noted. As this was part of a continuing program and the first part was done before the 1977 issue of the standard was available, it was decided to retain the same standards for this work. Also the Imperial units were used for a similar reason and for convenience in reporting results to the U.S. Corps of Engineers who maintain the exposure site.

2. Materials

(a) Cement

Type 10 cement was supplied by Canada Cement Lafarge Ltd. and was delivered in paper bags. All cement was free of lumps and was free flowing.

(b) Slag

The slag was delivered in metal drums and supplied by the Department of Energy, Mines and Resources.

(c) Silica

The silica fume was supplied by SKW Canada Inc. in a wooden box that was lined with plastic sheeting. The silica was free of lumps and was free flowing.

(d) Air-entraining Agent

The air-entraining agent was a sulphonated hydrocarbon type AEA supplied by W. R. Grace.

(e) Aggregates

The fine and coarse aggregates were from the Blagdon Pit and were delivered prior to the start of Phase IV. The results of tests carried out on the aggregates are listed in Appendix B.

(f) Superplasticizer

Superplasticizer was used to maintain slump when silica fumes were added to the mix. It was a sulphonated naphthelene condensate manufactured by KOA Soap Company and delivered in 5 gallon metal containers.

3. Batching and Mixing to Facilitate Handling.

To facilitate handling of the various ingredients and to enable adjustments to be made to the mix the ingredients were batched in two lots of equal size. To the skip was added one half the coarse aggregates, one half the cements and one half the fine aggregates. The mixer was started and the contents of the skip dumped into the mixer. Immediately prior to charging the mixer one half of the air-entraining admixture

was added to one half of the water and stirred. The sequence was such that the mixer was started and the contents of the skip added to the mixer simultaneously with the addition of the water and air-entraining admixture.

Mixing was continued for two minutes at which time the properties of the mix were evaluated, usually by visual inspection, and any changes that needed to be made were incorporated into the second half of the mix. The balance of the constituents of the mix were added and the full batch mixed for an additional five minutes. In most instances no changes needed to be made and in the instances where changes were made they were made in such a way as to maintain a given water-cement ratio. The ratio of fine to coarse aggregates was adjusted so as to produce a workable mix that could be placed using an immersion type vibrator in a concrete wall that contained a moderate amount of reinforcement. In all mixes containing silica fumes the silica fumes were added last, usually with the mixer stopped. The silica fumes were spread over the mixture and the mixer was then started. This was done so as to control the dust. The mixer was usually stopped for only about 15 seconds.

The mix description is given in Table 1. The plastic concrete was discharged into a wheelbarrow. Prior to testing the plastic concrete, the contents of the wheelbarrow were remixed with a shovel.

4. Testing of the Plastic Concrete

The concrete after remixing with a shovel was simultaneously tested for slump, air content and unit weight. A poker type vibrator was used to consolidate the concrete. The temperature of the concrete was measured using a steel jacketed thermometer. Table II contains the properties of the plastic concrete.

5. Testing of the Hardened Concrete

The unit weight of the six inch diameter concrete cylinders was measured and recorded in Table III.

Using the unit weight of the concrete and the batch proportions, the mix proportions per cubic yard were calculated and are recorded in Table IV. All weights of aggregates are given in a saturated surface-dry condition.

The compressive strengths at various ages are recorded in Table V. Table VI lists the modulus of elasticity of the concrete as determined by the ASTM 469-65 test at 28 days. Flexural tests were carried out at various ages and the results are recorded in Table VII. Specimens were tested for flexure according to ASTM C78-75 (third point loading). At the end of 90 days moist

curing the remaining concrete cylinders and prisms were taken out of the moist curing room. The cylinders were tested for compressive strength and the concrete prisms were transported to Eastport, Maine on November 7, 1982.

WORK STATEMENT

Program A - Concrete incorporating 80% pelletized blast-furnice slag

This program includes a total of 12 concrete mixes divided into three mix series.

Mix Series 1. In this Series, a $W/(C+S)^*$ ratio of 0.40 shall be used and four mixes shall be made as follows:

- Mix No. 1 Control - no slag
- 2 Repeat of Mix No. 1
- 3 Incorporating 80% slag (as replacement for cement)
- 4 Repeat of Mix No. 2

Mix Series 2: Mix Series 1 shall be repeated using a $W/(C+S)$ ratio of 0.50

Mix Series 3: Mix Series 1 shall be repeated using a $W/(C+S)$ ratio of 0.60

From each of the above mixes, one 305x305x915-mm prism and four 152x305-mm cylinders shall be cast. Before casting, properties of the fresh concrete such as temperature, slump, unit weight and air content shall be determined. Density of the hardened concrete shall be taken at one day or upon removing from the molds. All specimens shall be stored under moist curing conditions till being tested or shipped to the exposure site.

At 28 days, two cylinder specimens from each mix shall be tested in compression and for modulus of elasticity. The two remaining cylinders from each mix shall be tested in compression at the age of 90 days. All prisms shall be shipped to the exposure site (Treat Island) after a minimum of 90 days of moist curing.

Mix Proportioning Requirements

All mixes shall be proportioned to have a slump of approximately 75 mm (unless otherwise indicated) and an air content of 6 + 1%. Slag shall be incorporated in the mixes as a direct replacement by weight of cement. The $W/C+S$ ratio and $(C+S)$ content of mixes from a given Series shall be kept as constant as possible. Any substantial loss of slump due to the incorporation of slag shall be compensated for by the addition of a superplasticizer. In the advent of an increase in slump, no adjustment shall be made.

Program B - Concrete incorporating up to 20% silica fume

This program also includes a total of 12 concrete mixes divided into three mix series.

Mix Series 1: In this series, a W/C ratio of 0.60 shall be used and four air-entrained mixes shall be made as follows:

- Mix No. 1. Control - no silica fume
- 2. Incorporating 10% silica fume (as addition to cement)
- 3. Incorporating 15% silica fume (as addition to cement)
- 4. Incorporating 20% silica fume (as addition to cement)

Mix Series 2: Mix Series 1 shall be repeated with a $W/(C+SF)^{**}$ ratio of 0.60, the silica fume being incorporated as a replacement for cement.

Mix Series 3: Mix Series 2 shall be repeated with the mixes being non-air-entrained.

* $W/(C+S)$: water to cement plus slag ratio

** $X/(C+SF)$: water to cement plus silica fume ratio

From each of the above mixes, one 305x305x915-mm prism and four 152x305-mm cylinders shall be cast. Before casting, properties of the fresh concrete such as temperature, slump, unit weight and air content shall be determined. Density of the hardened concrete shall be taken at one day or upon removing from the molds. All specimens shall be stored under moist-curing conditions till being tested or shipped to the exposure site.

At 28 days, two cylinder specimens from each mix shall be tested in compression and for modulus of elasticity. The two remaining cylinders from each mix shall be tested in compression at the age of 90 days. All prisms shall be shipped to the exposure site (Treat Island) after a minimum of 90 days of moist curing.

Mix Proportioning Requirements

All mixes shall be proportioned to have a W/C (Mix Series 1) or a W/(C+SF) (Mix Series 2 and 3) ratio of 0.60 and a slump of approximately 75 mm. Silica fume shall be incorporated in the mixes as a direct addition by weight to cement (Series 1) or as a direct replacement by weight of cement (Series 2 and 3). In the latter case, the (C+SF) content for a given Series shall be kept as constant as possible. In all cases, any loss of slump due to the incorporation of silica fume shall be compensated for by the addition of a superplasticizer. For the air-entrained mixes (Series 1 and 2), the air content shall be maintained at 6±1%.

Program C - Concrete incorporating 80% slag and up to 15% silica fume

This program covers a total of 15 concrete mixes divided into three mix Series.

Mix Series 1: In this Series, a W/(C+S) ratio of 0.45 shall be used and five mixes shall be made as follows:

- Mix No. 1. Reference Mix - no slag or silica fume
- 2. Control 80% slag (as replacement) - no silica fume
- 3. 80% slag (replacement) 5% silica fume (addition)
- 4. 80% slag (replacement) - 10% silica fume (addition)
- 5. 80% slag (replacement) - 15% silica fume (addition)

Mix Series 2: Mix Series 1 shall be repeated using a W/(C+S) ratio of 0.60

Mix Series 3: Mix Series 1 shall be repeated using a W/(C+S) ratio of 0.75

From each of the above mixes, twelve 152x305-mm cylinders and six 75x100x400-mm prisms shall be cast. Before casting, properties of the fresh concrete such as temperature, slump, unit weight and air content shall be determined. Density of the hardened concrete shall be taken at one day or upon removing from the molds. All specimens shall be stored under moist-curing conditions until being tested.

Two cylinders from each mix shall be tested in compression at each of the following ages: 1d, 3d, 5d, 7d, 14d and 28d. At this latter age, modulus of elasticity shall also be determined. Two prisms from each mix shall be tested in flexure at each of the following ages: 3d, 7d and 14d.

Mix Proportioning Requirements

All mixes shall be non air-entrained and be proportioned to have a slump of approximately 75 mm (unless otherwise indicated). Slag shall be incorporated in the mixes as a direct replacement by weight of cement. For a given W/ (C+S) ratio, the (C+S) content shall be kept as constant as possible. Silica fume plus slag. Any loss of slump due to the incorporation of slag or slag and silica fume shall be compensated for by the addition of a superplasticizer. No adjustment shall be made in the case of an increase in slump.

Materials

All materials shall be provided by the contractor.

- (1) Normal portland cement (CSA Type 10) shall be used in all three programs.
- (2) Fine aggregate shall be natural gravel sand from New Brunswick and shall be used in all mixes.
- (3) Coarse aggregate shall be crushed limestone from New Brunswick; maximum size (nominal) shall be 25mm for programs A and B. For Program C, maximum size shall be 19 mm.
- (4) Slag shall be pelletized blast-furnace slag from Hamilton, Ontario (Standard Industries).
- (5) Silica fume shall be condensed silica fume from Becancour, Quebec (SKW Plant).
- (6) Superplasticizer shall be a sulphonated naphthalene condensate type.
- (7) Air-entraining agent shall be a sulphonated hydrocarbon type.

Appendix B

Sieve Analysis of Fine Aggregate

Sieve	% Passing	ASTM
#4	100	95 - 100
#8	78	80 - 100
16	55	50 - 85
30	36	25 - 60
50	20	10 - 30
100	7	2 - 10
200	1	-
Par	0	-

Sieve Analysis of Coarse Aggregate

Sieve Size	25 mm	19 mm
1	100	100
3/4	90	96
1/2	50	70
3/8	18	27
#4	1	1

NOTE: Mixes in Program A and B (M to R inclusive) used equal proportions of 19 and 25 mm size material whereas Program C (S to U inclusive) used 30% of the 25 mm size aggregate and 70% of the 19 mm size material.

TABLE 1

CONCRETE MIX DESCRIPTION

Series	% Slag	%Silica Fume	%Cement	W/C Ratio
M1	0	0	100	0.40
2	0	0	100	.4
3	80	0	20	.4
4	80	0	20	.4
N1	0	0	100	.5
2	0	0	100	.5
3	80	0	20	.5
4	80	0	20	.5
O1	0	0	100	.6
2	0	0	100	.6
3	80	0	20	.6
4	80	0	20	.6
P1	0	0	100	.6
2	0	10	100	.6
3	0	15	100	.6
4	0	20	100	.6
Q1	0	0	100	.6
2	0	10	90	.6
2	0	15	85	.6
4	0	20	80	.6
R1	0	0	100	.6
2	0	10	90	.6
3	0	15	85	.6
4	0	20	80	.6
S1	0	0	100	.45
2	80	0	~~50~~ 20	.45
3	80	5	~~50~~ 20	.45
4	80	10	~~50~~ 20	.45
5	80	15	~~50~~ 20	.45
T1	0	0	100	.6
2	80	0	20	.6
3	80	5	20	.6
4	80	10	20	.6
5	80	15	20	.6
U1	0	0	100	.75
2	80	0	20	.75
3	80	5	20	.75
4	80	10	20	.75
5	80	15	20	.75

TABLE II

PROPERTIES OF PLASTIC CONCRETE

Mix	Date Cast	Slump (mm)	Air Content %	Unit Wt. # /ft ³	Concrete Temp °C
M 1	82 07 13	95	6.5	144.4	25
2	82 07 13	89	5.9	146.5	26
3	82 07 13	82	5.8	146.2	24
4	82 07 13	95	6.2	145.0	24
N 1	82 07 15	88	6.3	147.6	25
2	82 07 15	70	5.6	147.4	25
3	82 07 15	82	6.0	144.9	24
4	82 07 15	98	6.7	143.0	24
O 1	82 07 19	88	5.2	146.6	25
2	82 07 19	75	5.5	147.4	25
3	82 07 19	108	6.3	142.8	23
4	82 07 19	102	6.1	144.6	24
P 1	82 07 07	82	6.4	144.7	24
2	82 07 07	73	6.5	143.3	24
3	82 07 07	78	5.3	145.5	24
4	82 07 07	92	6.3	143.7	24
Q 1	82 06 30	75	6.3	144.4	24
2	82 06 30	65	6.4	144.6	24
3	82 06 30	84	6.5	143.5	24
4	82 06 30	72	6.0	145.0	23
R 1	82 06 23	50	1.5	150.3	24
2	82 06 23	88	1.1	153.9	23
3	82 06 23	100	0.9	151.9	23
4	82 06 23	83	1.1	151.9	22
S 1	82 08 09	82	1.8	151.2	24
2	82 09 09	114	1.5	149.9	22
3	82 08 09	83	1.4	149.1	22
4	82 08 09	69	1.8	149.2	22
5	82 08 09	70	1.8	148.8	22
T 1	82 07 27	80	1.8	151.5	24
2	82 07 27	108	1.8	150.1	23
3	82 07 27	100	1.5	150.4	22
4	82 07 27	75	1.5	149.1	23
5	82 07 27	82	1.6	149.0	23
U 1	82 08 03	85	1.7	150.2	23
2	82 08 03	130	0.9	148.9	23
3	82 08 03	140	0.9	149.9	22
4	82 08 03	150	1.0	150.1	21
5	82 08 03	175	1.2	150.3	20

TABLE III

UNIT WEIGHT (LB./CU.FT.)

CYLINDER NO.	UNIT WT.	CYLINDER NO.	UNIT WT.	CYLINDER NO.	UNIT WT.
M1-1	145.3	01-1	148.4	Q1-1	144.8
2	144.1	2	148.4	2	145.1
3	143.8	3	148.5	3	145.3
4	144.8	4	148.3	4	144.8
M2-1	145.6	02-1	147.6	Q2-1	147.3
2	146.1	2	147.1	2	146.3
3	145.5	3	147.9	3	146.1
4	145.2	4	149.3	4	148.0
M3-1	144.9	03-1	142.9	Q3-1	145.5
2	144.9	2	142.2	2	146.1
3	144.4	3	143.2	3	145.8
4	144.6	4	142.8	4	146.0
M4-1	143.6	04-1	145.5	Q4-1	146.9
2	144.0	2	145.5	2	147.6
3	144.3	3	146.0	3	146.9
4	143.9	4	145.3	4	146.1
N1-1	145.9	P1-1	146.4	R1-1	153.4
2	145.9	2	145.4	2	153.0
3	145.3	3	146.2	3	153.4
4	145.6	4	145.3	4	153.6
N2-1	146.0	P2-1	145.2	R3-1	152.5
2	146.0	2	144.5	2	152.4
3	146.0	3	144.3	3	152.7
4	146.3	4	144.7	4	152.6
N3-1	145.6	P3-1	146.1	R3-1	153.3
2	144.7	2	147.2	2	153.2
3	145.5	3	146.7	3	153.0
4	144.6	4	147.2	4	153.2
N4-1	142.6	P4-1	144.6	R4-1	151.5
2	143.7	2	144.6	2	150.7
3	143.2	3	144.3	3	150.8
4	143.9	4	145.2	4	151.5

TABLE III

UNIT WEIGHT (LB./CU.FT.)

CYLINDER NO.	UNIT WT.	CYLINDER NO.	UNIT WT.	CYLINDER NO.	UNIT WT.
S1-1	x	T1-1	150.9	U1-1	149.5
2	x	2	151.3	2	149.6
3	151.3	3	151.6	3	150.1
4	150.9	4	151.6	4	150.3
5	151.6	5	151.1	5	149.5
6	150.9	6	151.4	6	149.6
7	151.1	7	151.5	7	149.9
8	151.5	8	151.6	8	149.8
9	151.2	9	151.3	9	150.0
10	151.2	10	151.8	10	149.4
11	151.8	11	151.4	11	149.6
12	151.6	12	151.9	12	149.9
S2-1	x	T2-1	151.0	U2-1	150.2
2	x	2	150.6	2	150.1
3	150.5	3	150.6	3	150.5
4	150.2	4	151.1	4	149.7
5	150.4	5	x	5	150.5
6	150.2	6	x	6	150.6
7	150.5	7	150.2	7	150.9
8	150.3	8	150.5	8	150.4
9	150.4	9	150.0	9	151.1
10	150.5	10	x	10	151.4
11	150.7	11	150.2	11	150.4
12	150.5	12	x	12	150.0
S3-1	x	T3-1	150.3	U3-1	150.7
2	x	2	150.4	2	150.7
3	149.1	3	149.8	3	150.4
4	149.2	4	149.6	4	150.4
5	149.3	5	144.7	5	150.2
6	148.8	6	150.2	6	150.4
7	149.2	7	150.3	7	150.0
8	148.9	8	150.6	8	150.3
9	149.5	9	149.7	9	150.2
10	148.8	10	149.7	10	150.0

TABLE III
UNIT WEIGHT (LB./CU.FT.)

CYLINDER NO.	UNIT WT.	CYLINDER NO.	UNIT WT.	CYLINDER NO.	UNIT WT.
S3-11	149.4	T3-11	150.00	U3-11	150.1
12	149.1	12	150.2	12	150.3
S4-1	x	T4-1	149.9	U4-1	149.7
2	x	2	149.7	2	150.2
3	149.5	3	149.4	3	150.5
4	148.7	4	149.3	4	149.9
5	148.8	5	149.1	5	150.6
6	149.0	6	149.5	6	150.2
7	148.9	7	149.1	7	149.8
8	148.9	8	149.3	8	150.3
9	149.0	9	149.4	9	149.7
10	149.1	10	149.5	10	149.8
11	149.2	11	149.2	11	150.2
12	149.2	12	149.6	12	150.4
S5-1	x	T5-1	149.3	U5-1	149.6
2	x	2	149.3	2	149.7
3	149.1	3	148.7	3	150.0
4	149.0	4	149.2	4	150.1
5	147.9	5	149.0	5	150.0
6	149.0	6	149.1	6	150.3
7	148.5	7	149.1	7	150.0
8	148.8	8	149.1	8	150.1
9	149.1	9	149.2	9	150.8
10	150.0	10	148.6	10	150.0
11	148.3	11	148.9	11	150.3
12	148.5	12	149.1	12	150.3

*Indicates Cylinders inadvertently missed during testing.

TABLE IV
MIX PROPORTIONS (In Lbs/ Cu.Yd.)

Mix	Silica Flume	Slag	Cement	Water	F.A.	C.A.	A/E Agent oz/100# Cements	Mighty 150 oz/100# Cements
M1	-	-	734	294	979	1888	1.59	-
2	-	-	746	298	994	1916	1.47	-
3	-	601	150	301	962	1932	4.28	3.1
4	-	596	149	298	955	1916	6.89	4.3
N1	-	-	554	276	1229	1934	1.20	-
2	-	-	552	274	1224	1926	1.15	-
3	-	436	109	273	1196	1904	3.27	1.7
4	-	431	108	269	1181	1880	5.16	1.7
O1	-	-	434	260	1266	1996	0.89	-
2	-	-	437	262	1271	2012	1.09	-
3	-	340	85	255	1220	1954	2.90	-
4	-	344	86	258	1236	1978	2.44	-
P1	-	-	439	264	1352	1855	1.25	-
2	43	-	434	262	1293	1833	2.06	5.4
3	66	-	441	266	1287	1863	2.52	12.1
4	88	-	437	264	1250	1848	3.95	14.7
Q1	-	-	409	246	1355	1897	1.29	-
2	41	-	368	246	1346	1897	2.75	10.4
3	61	-	347	246	1331	1897	3.57	16.7
4	83	-	330	248	1334	1913	4.37	17.4
R1	-	-	468	281	1412	1903	-	-
2	48	-	432	288	1429	1953	-	18.8
3	72	-	405	286	1410	1937	-	23.6
4	95	-	381	286	1405	1937	-	25.0
S1	-	-	697	314	1456	1612	-	-
2	-	558	139	314	1416	1612	-	1.7
3	35	558	139	314	1374	1612	-	2.6
4	70	556	139	313	1340	1606	-	7.3
5	104	558	139	314	1287	1612	-	9.7
T1	-	-	500	300	1616	1682	-	-
2	-	398	100	300	1583	1675	-	-
3	25	400	100	301	1559	1682	-	3.5
4	50	397	99	298	1516	1668	-	5.7
5	74	397	99	298	1485	1668	-	8.8
U1	-	-	422	317	1643	1677	-	-
2	-	336	84	315	1639	1671	-	-
3	21	336	84	315	1613	1671	-	-
4	42	338	84	317	1594	1677	-	-
5	64	339	85	318	1573	1683	-	-

NOTE: Cements include Silica Fume, Slag and Portland Cement.

TABLE V
COMPRESSIVE STRENGTH

CYLINDER No	STRENGTH IN PSI		CYLINDER No	STRENGTH IN PSI	
	28 days	90 days		28 days	90 days
M1-1	5126		01-1	4006	
2	3361		2	4129	
3		5707	3		4510
4		5760	4		4555
M2-1	5358		02-1	3665	
2	5344		2	3904	
3		4529	3		4482
4		5768	4		4515
M3-1	5343		03-1	2899	
2	5336		2	2882	
3		5481	3		3514
4		5585	4		3391
M4-1	4775		04-1	3348	
2	5284		2	3313	
3		5973	3		3900
4		5218	4		3682
N1-1	4396		P1-1	3887	
2	4423		2	3800	
3		5235	3		4428
4		5078	4		4319
N2-1	4761		P2-1	4881	
2	4565		2	4847	
3		5546	3		5235
4		5391	4		5375
N3-1	4178		P3-1	5606	
2	4196		2	4769	
3		4768	3		5376
4		4613	4		5183
N4-1	3747		P4-1	5639	
2	3934		2	5501	
3		4468	3		6230
4		4388	4		6545

TABLE V

COMPRESSIVE STRENGTH

CYLINDER	STRENGTH IN PSI		CYLINDER	STRENGTH IN PSI	
	28 days	90 days		28 days	90 days
Q1-1	3696		R1-1	5253	
2	3672		2	5195	
3		4018	3		5926
4		4164	4		5634
Q2-1	5245		R2-1	6306	
2	4800		2	6387	
3		5304	3		6889
4		5111	4		7009
Q3-1	5144		R3-1	6365	
2	5375		2	6643	
3		5939	3		6894
4		6126	4		7136
Q4-1	5686		R4-1	6595	
2	5595		2	6429	
3		6149	3		5790
4		5973	4		6427

TABLE V Cont'd.
STRENGTH AT AGE IN DAYS OF

	1	3	5	7	14	28
S1-1	4450					
2	4447					
3		5302				
4		5375				
5			5332			
6			4188			
7				5312		
8				5357		
9					6433	
10					5920	
11						6957
12						7599
S2-1	1072					
2	1131					
3		4157				
4		4058				
5			4480			
6			4775			
7				4708		
8				4621		
9					5462	
10					5527	
11						6469
12						5931
S3-1	1236					
2	1195					
3		4417				
4		4540				
5			4917			
6			4924			
7				4881		
8				5246		
9					6089	
10					6015	
11						6851
12						6521

S4-1	1451								
2	1436								
3		4705							
4		5035							
5			5412						
6			5355						
7				5411					
8				5471					
9					6314				
10					5822				
11							7018		
12							6974		
S5-1	1895								
2	1856								
3		5183							
4		5280							
5			5207						
6			5811						
7				5511					
8				5850					
9					6676				
10					5409				
11							8034		
12							7326		
T1-1	2600								
2	2475								
3		3569							
4		3634							
5			4009						
6			3929						
7				4255					
8				4198					
9					4573				
10					4671				
11							5494		
12							5468		

-22-
TABLE V Cont'd.

	1	3	5	7	14	28
T2-1	557					
2	583					
3		1773				
4		1722				
5			2656			
6			2651			
7				3285		
8				3204		
9					3428	
10					3897	
11						4675
12						4511
T3-1	611					
2	609					
3		2206				
4		2115				
5			3112			
6			2922			
7				3690		
8				3701		
9					4243	
10					4086	
11						5052
12						4764
T4-1	661					
2	730					
3		2633				
4		2686				
5			3545			
6			3833			
7				3963		
8				3925		
9					4314	
10					4524	
11						5160
12						4917

TABLE V CONT'D.

	1	3	5	7	14	28
T5-1	875					
2	894					
3		3148				
4		3058				
5			4171			
6			4122			
7				4508		
8				4779		
9					4931	
10					5062	
11						5802
12						5774
U1-1	1292					
2	1687					
3		2703				
4		2795				
5			3081			
6			3039			
7				3120		
8				3117		
9					3950	
10					3675	
11						4017
12						3883
U2-1	256					
2	238					
3		1574				
4		1537				
5			2224			
6			2147			
7				2361		
8				2436		
9					3414	
10					3287	
11						3583
12						3554

	1	3	5	7	14	28
U3-1	216					
2	230					
3		1544				
4		1592				
5			2294			
6			2210			
7				2390		
8				2231		
9					3363	
10					3277	
11						3774
12						3777
U4-1	194					
2	193					
3		1325				
4		1268				
5			1992			
6			2037			
7				2111		
8				2076		
9					3000	
10					3074	
11						3331
12						3356
U5-1	177					
2	177					
3		1222				
4		1190				
5			1736			
6			1958			
7				1881		
8				1909		
9					2829	
10					2577	
11						3208
12						3248

TABLE VI
MODULUS OF ELASTICITY
At 28 Days

CYLINDER NO.	MODULUS OF ELASTICITY IN PSI x 10 ³	CYLINDER NO.	MODULUS OF ELASTICITY IN PSI x 10 ³
M1-1	5115	Q1-1	4046
2	4804	2	4221
M2-1	4734	Q2-1	4969
2	5181	2	4236
M3-1	4703	Q3-1	4952
2	4925	2	4966
M4-1	4769	Q4-1	4914
2	4664	2	5010
N1-1	4937	R1-1	5510
2	4382	2	4985
N2-1	4857	R2-1	5645
2	4643	2	5441
N3-1	4751	R3-1	5558
2	4613	2	5477
N4-1	3948	R4-1	5372
2	4378	2	5380
O1-1	4422	S1-11	5773
2	4415	12	5854
O2-1	4511	S2-11	5985
2	4311	12	5540
O3-1	3835	S3-11	5384
2	3620	12	5163
O4-1	4161	S4-11	5159
2	4129	12	5255
P1-1	4496	S5-11	5085
2	4266	12	5086
P2-1	4735	T1-11	x
2	4278	12	x
P3-1	5527	T2-11	x
2	5298	12	x
P4-1	5271	T3-11	x
2	4887	12	x

NOTE x Specimens inadvertently tested for compressive strength only

TABLE VI MODULUS OF ELASTICITY Cont'd.

CYLINDER NO.	MODULUS OF ELASTICITY IN PSI x 10 ³	CYLINDER NO.	MODULUS OF ELASTICITY IN PSI x 10 ³
T4-11	x	U3-11	4032
12	x	12	4519
T5-11	x	U4-11	4158
12	x	12	4097
U1-11	3885	U5-11	3936
12	4098	12	3929
U2-11	4247		
12	4227		

NOTE x Specimens inadvertently tested for compressive strength only

TABLE VII
FLEXURAL STRENGTH In psi

SPECIMEN NO.	AGE IN DAYS		
	3	7	14
S1-1	772		
2	878		
3		772	
4		957	
5			1019
6			1000
S2-1	765		
2	679		
3		839	
4		946	
5			1081
6			1424
S3-1	686		
2	771		
3		861	
4		1010	
5			1215
6			1149
S4-1	852		
2	799		
3		868	
4		992	
5			1122
6			1056
S5-1	822		
2	799		
3		904	
4		1053	
5			1226
6			1225
T1-1	713		
2	649		
3		766	
4		688	
5			725
6			731

TABLE VII FLEXURAL STRENGTH IN psi

SPECIMEN NO.	AGE IN DAYS		
	3	7	14
T2-1	468		
2	431		
3		656	
4		640	
5			820
6			712
T3-1	392		
2	386		
3		668	
4		702	
5			832
6			743
T4-1	472		
2	438		
3		734	
4		773	
5			878
6			848
T5-1	501		
2	512		
3		842	
4		747	
5			1012
6			962
U1-1	546		
2	579		
3		593	
4		561	
5			654
6			750
U2-1	270		
2	244		
3		425	
4		430	
5			581
6			780

TABLE VII cont'd. FLEXURAL STRENGTH IN psi

SPECIMEN NO.	AGE IN DAYS		
	3	7	14
U3-1	261		
2	265		
3		506	
4		470	
5			624
6			605
U4-1	198		
2	222		
3		509	
4		465	
5			657
6			960
U5-1	200		
2	202		
3		435	
4		477	
5			755
6			730

POOR

QUALITY

ORIGINAL